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(54) Endoscope

(57) An endoscope has a lens and an optical image transmission system to transmit an image formed by the lens. The optical image transmission system consists of at least one bar lens (21) and a reinforcing part (22) that is located peripheral to the bar lens (21). In other words, the endoscope is constructed such that the transmission lenses are not damaged and a clear image is always visible, even when the insertion piece of the endoscope is bent during use or storage.

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The following representations are taken from the documents filed by the applicant

Description

This invention relates to an endoscope for use in the areas of medicine or industry.

Figures 1A and 1B show the optical systems of conventional rigid endoscopes. In Figure 1A, the image of an object O that is formed on a plane O1 by a lens Obj, is transmitted while being repeatedly formed on planes O2 and O3 by transmission lenses 2a and 2b that comprise an optical image transmission system so that the image formed on plane O3 is enlarged for viewing through an eyepiece 3. Reference numbers 1a and 1b represent field lenses. In this case, it is known that when, as shown in Figure 1B, bar-shaped transmission lenses 2a' and 2b' are used instead of transmission lenses 2a and 2b, the brightness of the optical system is equal to the square of the refractive index of each of the bar-shaped lenses 2a' and 2b', in comparison with the optical system shown in Figure 1A, in which the spaces between the individual lenses are filled with air.

The frame structure of a rigid endoscope with the optical system shown in Figure 1B is known from disclosure in US patent No. 5,020,893. Figure 2A shows the rigid endoscope that is described therein. In Figure 2A, reference number 1 represents an endoscope handle, 2 an eyepiece, and 3 an endoscope insertion piece or shaft. Figure 2B describes the internal form of an insertion piece 3 in which an optical fiber 7 used to illuminate an object is positioned adjacent to an optical system tube 10, which contains the optical image transmission system. The optical system tube 10 contains a lens 8, transmission lenses 9 consisting of bar-shaped lenses 12 for transmitting an image, and spacing rings 11, positioned to maintain a constant distance between the lenses.

The rigid endoscope constructed as described above is used in such a way that the insertion piece 3 is inserted into a small opening in a human body or device. In this case, when the insertion piece 3 is subjected to bending, it is difficult to withdraw the insertion piece 3 after having inserted it. As a result, with the exception of the optical fiber 7 and individual lenses, the parts that form the insertion piece 3 are generally constructed of metals that are relatively hard.

Figures 3A and 3B show conditions under which the insertion piece of the rigid endoscope is introduced into a human body. In practical terms, very few cases have been reported in which the insertion piece is inserted into the human body straight as shown in Figure 3A. It is more frequently the case as shown in Figure 3B that the insertion piece at the eyepiece (ocular) end A of the rigid endoscope is bent in order to insert it into the human body. When the rigid endoscope is used specifically for diagnosis of the urinary organs such as those described in the figure, finding the entrance to the ureter in the bladder is done in such a way that forces from all directions act upon the eyepiece end A while the insertion piece is guided in the right direction. This action subjects the insertion piece to bending. Such bending of the insertion piece of the rigid endoscope during use can also occur when it is used in internal medicine, obstetrics and gynecology, and surgery as well as in industrial applications. The rigid endoscope is placed under even higher stress in industry than in medicine. In addition, the insertion piece of the rigid endoscope must have a higher level of flexural strength because it is often used under conditions of relatively high load such as when the insertion piece is introduced into a small metal hole in order to observe the insides of a machine or water pipe.

During storage of the rigid endoscope such as, for example, on a base (see Figure 4A), it can easily happen that a heavy weight such as a tool can accidentally be laid on top of the rigid endoscope (see Figure 4B). This results in unilateral load exerted on the insertion piece, which may then be bent (reference symbol B in the figure).

When the insertion piece of the rigid endoscope is bent, as shown in Figure 5, high unilateral load is exerted on the contact parts of the tube 10 with the transmission lenses 9, particularly on the faces of the transmission lenses 9, designated by symbols C1 and C2, and the metallic spacing rings 11. In this case, depending on the extent of unilateral load, the transmission lenses 9 may be damaged such that cracks or breaks may occur. This causes great deterioration in the observed image. Figures 6A and 6B show how the observed image deteriorates as a result of damage to the lens. Figured 6A shows how cracks in the center of the lens result in a decrease in the light beam, which throws a shadow on a large portion of the

observation field, leading to a degraded image. If the cracks expand to the point where the lens finally breaks completely, no light beam is transmitted, as shown in Figure 6B, and the observation field is completely dark.

As mentioned above, the problem with the conventional rigid endoscope is that each transmission lens in the insertion piece 3 can be broken off during use or storage.

It is therefore a task of the present invention to create a rigid endoscope in which damage to the transmission lenses is prevented and a clear image is always visible, even when the insertion piece of the rigid endoscope is bent during use or storage.

In order to fulfill this task, the rigid endoscope according to the invention must, viewed from the object, have a lens and an optical image transmission system to transmit an image that is created by the lens. The rigid endoscope is characterized in that the optical image transmission system contains at least one bar lens and in that a reinforcing part is located at the periphery or circumferential surface of the bar lens. In a preferred embodiment, the reinforcing part is shorter than the bar lens, and the material of which the reinforcing part is made meets the condition:

$$y < Y \qquad (1),$$

where y represents the Young's modulus of the bar lens, and Y the Young's modulus of the reinforcing part.

The rigid endoscope is further characterized in that the length ratio between the reinforcing part and the bar lens meets the condition:

$$0.3 \leq l/L \leq 0.9 \qquad (2),$$

in which case l represents the length of the reinforcing part, and L the length of the bar lens.

The rigid endoscope is further characterized in that one can differentiate between the front and back sides of the reinforcing part, and in that it has a window to facilitate hardening of a bonding material, and in that the bar lens consists of a bonded lens and that the reinforcing part is attached such that the joining surface of the bonded lens is covered.

The function of the rigid endoscope will be explained in the following. Using Figure 5, we will first discuss the process by which strong flexural loading acts on the insertion piece of the rigid endoscope, which leads to breakage of the bar lens. As Figure 5 shows, external flexural loading causes a strong shift. As a result of such bending, the upper and lower parts of the optical system tube 10 of the rigid endoscope vary in their length so that one side of the tube 10 comes under such tension that it separates from the lenses, while the other side is compressed so that it impinges on the lenses. Consequently, the forces that deform each lens act on the three points A, B, and C as shown in the figure. However, load on the material is increasingly concentrated on the bar lens as deformation continues because the flexural load on points B and C concentrates on and around the center of the bar lens, eventually causing it to break.

Therefore, as illustrated in Figure 7, the rigid endoscope in the present invention contains a reinforcing part 22 that is shorter than a bar lens 21 that is inserted between the periphery of the bar lens 21 and the optical system tube 10, such that the load exerted on the material does not act on the bar lens 21 during the first phase of deformation of the optical system tube 10. Even with extreme deformation, the bar lens 21 resists bending because the reinforcing part 22 is subjected to the stress, while at the same time the central part of the bar lens 21 and its surroundings where the stress is concentrated are protected by the reinforcing part 22.

During the first phase of deformation, particularly during the period from free deformation to the time when the internal diameter of the optical system tube 10 and corner points B and C of the bar lens 21 touch there is only minor tension on the bar lens 21. This is meant to ensure that the deflection R of the optical system tube 10 during free deformation is as minor as possible. The three points B, C, and D determine the deflection R. In the conventional rigid endoscope without a reinforcing part, the extent of

the shift of point D in relation to points B and C depends on the space into which the bar lens 21 is fit in the optical system tube 10. However, it is difficult to enlarge this space because this leads to decentering of the lens. Although consideration has also been given to decreasing the space between points B and O, this size, i.e., the length of the bar lens, is determined by the specifications of the product and is therefore difficult to change. According to the invention, however, it is possible to minimize bending R during free deformation because the reinforcing part 22 is mounted around the bar lens 21 in order to equalize the degree of shift of point D in relation to points B and O.

To ensure that bending stress does not act directly on the bar lens 21, the reinforcing part 22 functions as a reinforcement after free deformation so that the bar lens 21 is difficult to bend. For this reason, the reinforcing part 22 is, in contrast to the lens, made of a very tough material like metal or ceramic. The length of the reinforcing part 22 is optimized such that when stress is exerted on the bar lens 21, the reinforcing part 22 makes contact at points E and F with the tube 10 and absorbs the stress in order to protect the bar lens from deformation. Because the contact distance of the reinforcing part 22 (between points E and F) is shorter than that of the bar lens 21 (between points B and C) the reinforcing part 22 has the advantage that it is difficult to bend even with regard to bending moment. Stress is concentrated at the center of the bar lens 21. A greater level of reinforcement is achieved if the reinforcing part 22 is constructed such that it covers the center of the bar lens 21 and its surroundings.

It is particularly desirable that the material of which the reinforcing part 22 is made meets the conditions in equation (1). Furthermore, the length ratio between the bar lens 21 and the reinforcing part 22 should meet the conditions in equation (2). If the value of (l/L) exceeds the lower limit value of equation (2), the reinforcing part 22 is too short to neutralize the effect of decentering brought about by deflection of the bar lens 21. Before the reinforcing part 22 makes contact with the optical system tube 10, strong tension is exerted on the bar lens 21, and the lens breaks off. If, on the other hand, the value of (l/L) exceeds the upper limit value in equation (2), the reinforcing part 22 is too long to minimize bending R during free deformation.

The insertion piece of the rigid endoscope is bent when it is relatively thin. An external diameter Ø of the bar lens of approximately 5 mm or less is used in such a rigid endoscope, which brings with it the problem of breakage of the bar lens and detachment of the joining surface. Experiments have shown that, for example, a bar lens with an external diameter of Ø = 3 mm and a length L = 30 mm breaks in the middle when the bending stress is so strong that the bar lens itself has a bend R = 1000 mm or less. Because of this fact, it is desirable that the length of the reinforcing part be such that free deformation can occur with a deflection R as great as 1000 mm.

With regard to thickness t of the reinforcing part, greater thickness is preferred in order to minimize deflection R and increase the reinforcement effect. However, extreme thickness decreases the effective diameter of the transmission lens and darkens the observation field. Furthermore, it is important that the reduction in light quantity brought about by the inclusion of the reinforcing part be held to 30% or less. It is desirable for the ratio between the thickness t of the reinforcing part and the external diameter Ø of the bar lens meet the condition:

$$t \leq 0.1\,\varnothing \qquad (3).$$

When assembling the rigid endoscope, a contrivance is often needed to differentiate between the front and back of the bar lens. It is advantageous in this case if the front and back of the bar lens can be differentiated by fitting the reinforcing part with a contrivance that allows such differentiation or in that the reinforcing part is some distance away from the center of the bar lens, because then assembly is considerably easier.

When assembling the reinforcing part and the bar lens, decentering of the bar lens is minimized and flexural strength increased if a medium of the same form is introduced into the entire space between the external face of the bar lens and the internal face of the reinforcing part. This is advantageous when the device is put into actual use. The choice of medium to be introduced does not have to be limited to bonding material. It can be silicon, for example.

In addition, it is possible according to the invention to improve flexural strength independent of the construction of the bar lens (i.e., of the possible effect of the bonded lens and the position of the joining surface). A particularly great effect may be expected where the joining surface is in the center portion of the bar lens where flexural tension is concentrated.

This and other tasks, as well as the characteristics and advantages of the present invention are made clear in the following detailed description of the preferred embodiments in connection with the attached diagrams. They show:

Figure 1A and 1B, a view of optical systems with conventional rigid endoscopes;

Figure 2A, a view of significant parts of the conventional rigid endoscope;

Figure 2B, a sectional view of a part identified by the symbol I in Figure 2A;

Figure 3A and 3B, explanatory views of the conditions in which the rigid endoscope is inserted into a human body;

Figure 4A and 4B, explanatory views of the conditions under which the rigid endoscope is stored;

Figure 5, an explanatory view of a condition under which the transmission lenses of an insertion piece of the conventional rigid endoscope is broken by bending;

Figure 6A and 6B, explanatory views of the conditions under which the observation image deteriorates as a result of cracks or breakage of the lens;

Figure 7, a view of the basic construction of the significant parts of the rigid endoscope according to the invention;

Figure 8, a view of the construction of the first to third embodiments of the rigid endoscope according to the invention;

Figure 9, a view of the construction of a fourth embodiment;

Figure 10, a view of the construction of a fifth embodiment;

Figure 11A, a view of the construction of a sixth embodiment;

Figure 11B, a view of a section along the D-D line as shown in Figure 11A; and

Figure 12A, 12B, 12C, and 12D, examples of the use of the rigid endoscope according to the invention in a variety of different optical transmission systems.

Detailed description of the preferred embodiments

The embodiments of the present invention are explained in the following with reference to the diagrams.

First embodiment

Figure 8 shows the construction of this embodiment. Below are the figures relating to the first embodiment:
Deflection R = 2000 mm
Length of the bar lens, L = 30 mm
Thickness of the reinforcing part, t = 0.08 mm
Length of the reinforcing part, l = 22 mm
External diameter of the bar lens, Ø = 3 mm
(l/L) = 73%
Young's modulus of the bar lens, y = 8.02 x 10^{10} (N/m^2)
Young's modulus of the reinforcing part, Y = 1.3 x 10^{11} (N/m^2)

Second embodiment

Because the construction of this embodiment is the same as that of the first embodiment, the corresponding figure has been left out. Below are the data relating to the second embodiment:
Deflection R = 1000 mm
Length of the bar lens, L = 30 mm

Thickness of the reinforcing part, t = 0.08 mm
Length of the reinforcing part, l = 15 mm
External diameter of the bar lens, Ø = 3 mm
(l/L) = 50 %
Young's modulus of the bar lens, y = 8.02×10^{10} (N/m^2)
Young's modulus of the reinforcing part, Y = 1.3×10^{11} (N/m^2)

Third embodiment

Because the construction of this embodiment is the same as that of the first embodiment, the corresponding figure has been left out. . Below are the figures relating to the third embodiment:
Deflection R = 800 mm
Length of the bar lens, L = 30 mm
Thickness of the reinforcing part, t = 0.08 mm
Length of the reinforcing part, l = 7.5 mm
External diameter of the bar lens, Ø = 3 mm
(l/L) = 50 %
Young's modulus of the bar lens, y = 8.02×10^{10} (N/m^2)
Young's modulus of the reinforcing part, Y = 1.3×10^{11} (N/m^2)

Fourth embodiment

Figure 9 shows the construction of this embodiment. The bar lens 21 is constructed as a bonded lens, and one end 22a of the reinforcing part 22 is cut off diagonally in order to differentiate the front from the back of the bar lens.

Fifth embodiment

Figure 10 shows the construction of this embodiment. When the bar lens 21 and the reinforcing part 22 are bonded with an adhesive as shown in the figure, it is recommended that the reinforcing part 22 be fitted with a window 22b in such a way that its stability is not reduced. A particularly high bonding effect is achieved by using a bonding material that hardens under UV light. If correctly shaped and positioned, the window 22b also serves as a contrivance to differentiate the direction of the bar lens 21.

Sixth embodiment

Figures 11A and 11B show the construction of this embodiment. Flat faces are arranged along the length of the periphery of the bar lens 21. When the bar lens 21 is formed in this manner, the flat faces of the lens 21 are lowerable in relation to the reinforcing part 22. This makes it possible to minimize bending during free deformation. In order to enable free deformation in all directions, it is necessary to furnish the bar lens 21 with numerous flat faces. However, because this decreases the effective diameter of the bar lens 21, it is advantageous to create three flat faces, as in this embodiment.

Over and above that, the present invention as shown in Figures 12A to 12D may be used in various types of optical transmission systems. Each of the optical systems shown in the figures is set for a single image transmission. The optical system shown in Figure 12A exhibits a bonded converging lens 32 that is situated between two plano-convex lenses 31 and 31' that have the reinforcing parts 33 and 33', respectively, at their peripheries. The spaces between the bar lenses and the bonded lens are maintained by spacing rings 34 and 34' arranged in a previously determined configuration. The external diameter of the bonded lens is somewhat larger than the external diameter of the bar lenses. These components are fit into the optical system tube. The optical system in Figure 12B exhibits two biconvex bonded bar lenses 35 and 35' that are fitted at their peripheries with reinforcing tubes 36 and 36', respectively.

Reference number 37 designates a spacing ring. The optical system in Figure 12C includes two bar lenses, in which case both have plano-convex lenses 39 that are bonded to one end of a glass bar 38, and whose end faces are flat. A plano-convex lens 40 is bonded to the other end of the glass bar 38. The glass bars of the bar lenses are fitted with reinforcing tubes 41 and 41'.

Reference number 42 designates a spacing ring. The optical system in Figure 12D is actually identical to that shown in Figure 12B; however, parts of the periphery of each bar lens are cut off to form flat faces. As explained in connection with Figure 11A and 11B, the flat parts are formed, and they establish a large space (the upper side of the figure) between the bar lens and the optical system tube.

The endoscope is thus constructed such that the transmission lenses are not damaged, and in that a clear image is always visible even when the insertion piece of the endoscope is bent during a use or storage.

Patent claims

1. Endoscope with an insertion piece (3) that protrudes lengthwise and at least one bar lens (21) in the insertion piece, **characterized in that** the bar lens (21) exhibits means to increase flexural strength at its periphery or circumferential surface.
2. Endoscope according to claim 1, characterized in that it exhibits one lens at the distal end of the insertion piece, and in that the image of an object formed by the lens is transmitted by an optical transmission system with the bar lens, in which case the means by which flexural strength is increased is a reinforcing part (22) at the periphery or circumferential surface of the bar lens (21).
3. Endoscope according to claim 1 or 2, characterized in that the means by which flexural strength is increased is shorter than the bar lens (21)
4. Endoscope according to one of claims 1 to 3, characterized in that a material for the reinforcing part (22) meets a condition:

$$y < Y,$$

in which case y is the Young's modulus of the bar lens (21), and Y the Young's modulus of the reinforcing part (21).
5. Endoscope according to one of claims 1 to 4, characterized in that the length ratio between the means by which flexural strength is increased and the bar lens (22) meets a condition:

$$0.3 \leq l/L \leq 0.9,$$

in which case l is the length of means whereby flexural strength is increased, and L is the length of the bar lens (21).
6. Endoscope according to one of claims 1 to 5, characterized in that the reinforcing part (22) has means for differentiating between the front and back of the bar lens (22).
7. Endoscope according to one of claims 1 to 6, characterized in that the reinforcing part has a window that facilitates hardening of the adhesive.
8. Endoscope according to one of claims 1 to 7, characterized in that the bar lens (21) exhibits a bonded lens, and the means by which flexural strength is increased is attached in such a way that a joining surface of the bonded lens is covered.
9. Endoscope according to one of claims 1 to 8, characterized in that the reinforcing part (22) consists of metal or ceramic
10. Endoscope according to one of claims 1 to 9, characterized in that the means by which flexural strength is increased meets a condition:

$$t \leq 0.1\,\varnothing,$$

in which case t is the thickness of the means by which flexural strength is increased, and Ø is the external diameter of the bar lens (21).

6 pages of diagrams appended

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Rigid Endoscope

Description:

The invention originates from an endoscope with the characteristics contained in the preamble to claim 1. Such an endoscope is known from DE 38 18 104 A1 (see figures 23 and 8 therein). The known endoscope has a slender shaft in the form of a rigid jacket tube in which two parallel guide tubes are provided that extends from two lenses that are located at the distal end of the shaft all the way to a headpiece that is located at the proximal end of the shaft, and that have adjacent to each other two oculars or adapting optics for an image taking or imaging device, particularly for a CCD camera. The two guide tubes each contain an optical transmission system with several bar lenses in succession. Bar lenses are, as their term suggests, bar-shaped lenses that consist either of a base bar with flat end faces, in which case a lens, if necessary a multiple lens, is bonded to one or both of the end faces, or they consist of a bar that has a spherical or an aspherical curved surface, or a spherical or an aspherical curved surface at one end and a flat surface at the opposite end, to which a lens may be bonded. The known endoscope

allows stereoptic observation of objects. Because the two guide tubes lie immediately adjacent to each other, they must, in order to enable stereoptic observation, both be adjusted to eye distance by means of the beam paths that pass through them, or pass through a subsidiary imaging device such as a CCD camera at a preset distance from each other. For that purpose, two pairs of prisms are provided in the headpiece, which collect the light beams emitted by both transmission systems in the guide tubes and then direct them to the oculars that are provided at a larger distance.

This has the disadvantage that compared to a monocular endoscope without parallel beam displacement but that is otherwise identically designed and in which identical optical elements are arranged, additional glass pathways and additional refractive surfaces are introduced, which decrease image brightness and sharpness as a result of additional absorption and reflection loss. In addition, the prisms inserted into the beam path emitted by a monocular endoscope with a straight beam path require recalculation of the optical system.

The task of the present invention is to improve a rigid endoscope of the aforementioned type such that the bends in its beam path needed to achieve beam displacement are associated with less loss in image brightness and sharpness.

This task is solved by means of an endoscope with the characteristics listed in claimed 1. The advantageous developments of the invention are the subject of the dependent claims.

In contrast to the state-of-the-art, according to the invention the beam path through the endoscope is not bent by providing two individual prisms that are provided as an additional element between the ocular and the optical transmission system, which creates the optical connection between the lens and the ocular. Rather, the provision of prisms according to the invention is a component of a bar lens of the optical transmission system. The bar lens in this case can take the form of a base bar with two flat end surfaces that run at a right angle to the longitudinal axis of the base bar, a prism being attached, in particular bonded, to each end surface at its one entry face or exit face,

respectively, if necessary with the insertion of a spacing piece. This results in twofold beam deviation, which makes beam displacement possible. It is, however, also possible to provide a prism only at one end of the base bar. The single beam deviation that results can be used in a monocular endoscope to take the ocular out of the shaft alignment, thereby creating space for instruments that are inserted straight into the shaft, and which can be operated in the space behind the proximal end of the shaft.

Instead of the oculars, adapting optics may be provided for imaging or image creation devices such as cameras that are associated with the endoscope. The term ocular is used in a general sense to include such adapting optics as well.

However, twofold beam deviation can also be achieved with bar lenses that have a prism only at one end of their base bar when such bar lenses are arranged successively in the beam path.

Instead of attaching special prisms to the base bar of the bar lens, the base bar can itself be formed as a prism by having its end faces slanted to the longitudinal axis of the base bar instead of at right angles. This has the advantage that the prisms need not be specially produced and bonded to the base bar, but that one can simply fit the base bar with one or several lenses that turn it into a bar lens, similar to an endoscope with a completely straight light path.

In all cited cases, the bar lens that is designed as a deviating prism can be designed in such a way that when observing the beam that runs along the optical axis, the incident beam and the emergent beam lie along a common plane and deviation occurs at a right angle. However, it is equally feasible to deviate the beam at angles other than 90° and/or to allow the incident beam and the emergent beam to run along different planes.

The invention has the following advantages:

1.

Because the deviating prisms are integrated into the bar lens that is necessary in any case, no additional refractory faces are needed in comparison with an endoscope with a straight beam path and a comparable optical system. Beam deviation therefore entails no particular loss in reflection, so that the usual decreases in image brightness and quality are avoided.

2.

Because the deviating prisms are integrated into the bar lens that is necessary in any case, no additional beam path is required in the glass; rather, the beam path needed for beam deviation can (when prisms are attached to the base bar of the bar lens, this is the beam path that runs through the prisms) then be taken into consideration beforehand when measuring the length of the base bar, so that in contrast to the state-of-the-art in which deviation prisms are add-on elements between the optical transmission system, consisting of bar lenses and the ocular, respectively, according to the invention no lengthening of the beam path in the glass occurs. As a result, beam deviation entails no absorption losses, and therefore no resultant decrease in image brightness and quality, which is extremely important for endoscopes in which no beam cross-sections are being attempted.

3.

Existing optical transmission systems with bar lenses that have been designed and built with a straight beam path for endoscopes can be integrated without further calculation and few additional construction costs into endoscopes in which beam deviation, in particular beam displacement, is desired, both in stereoscopic endoscopes and in monocular endoscopes. This represents a significant cost advantage.

Recalculation of an optical system that is to be transposed from an endoscope with a straight beam path to one with beam deviation is thus indispensable, because the arrangement of prisms responsible for the beam deviation is a component of a bar lens of the optical transmission system, for which the calculation already exists. Whether a bend occurs in the base bar of the bar lens or in prisms set into the base bar is irrelevant for the

calculation of the bar lens, at least to the extent that the beam path in the bar lens is not significantly lengthened or shortened. This is the case when the length of the beam path in the base bar and prism combination is between 65% and 150% of the length of the base bar of the bar lens, which assumes an existing straight-line bar lens system that is to be modified without recalculation for the purpose of beam deviation or beam displacement, respectively.

Of course it is important that the material used for the prisms is not different from that used for the base bar of the bar lens or that it be at least similar in its optical properties not only when the base bar of the bar lens is in itself in the form of a prism (claim 3), but also when the prisms are bonded to the face of base bar as separate elements, in order that there be no significant loss of quality in the optical data of the entire optical transmission system, if this is not recalculated.

4.

As a result of the integration of the prisms into a bar lens, the dimensions of the optical system can be kept small, which is particularly important for an endoscope.

Because the prisms are integrated into a bar lens, they don't have to be adjusted separately when installing them into the endoscope housing, which greatly facilitates assembly. An endoscope with beam displacement according to the invention does not contain more separate optical components than does a comparable endoscope without beam displacement.

There are no particular limits to the type of prism that can be used. Triangular prisms, pentagonal prisms, rhomboidal prisms, Wollaston prisms, Porro prisms, and other prisms can all be used, in which case rhomboidal prisms and rhomboid-like prisms are particularly preferable. The entry face and the exit face of the prisms are preferably rectangular or quadratic, because then production, mounting in the endoscope housing, and adjustment are facilitated.

The embodiments of the invention are schematically depicted in the attached diagrams.

Figure 1 shows a longitudinal section of a stereoendoscope,

Figure 2 shows a side view of a bar lens according to the invention with beam deviation only at one end,

Figure 3 shows a top view of the bar lens in Figure 2,

Figure 4 shows a left frontal view of the bar lens from the view in Figure 3,

Figure 5 shows a modification of the diagram in Figure 4 with a larger lens,

Figure 6 shows a modification of the diagram in Figure 4 with a smaller lens,

Figure 7 shows a top view of an example of a bar lens according to the invention with beam deviation at both ends,

Figure 8 shows a side view of the bar lens in Figure 7,

Figure 9 shows a frontal view of the bar lens from the view in Figure 7,

Figure 10 shows a modification of the diagram in Figure 9 with smaller lenses,

Figure 11 shows a modification of the diagram in Figure 9 with larger lenses,

Figure 12 shows a frontal view of a further embodiment of a bar lens according to the invention whose base bar has a hexagonal cross-section,

Figure 13 shows a side view in the direction of arrow A in Figure 12 of a section of the bar lens in Figure 12,

Figure 14 shows a modification of the bar lens depicted in Figure 12, whose base bar has the form of a circular face in cross-section,

Figure 15 shows an oblique view of a further embodiment of a bar lens according to the invention, in which the incident beam and the emergent beam lie on a common plane,

Figure 16 shows an oblique view of a further embodiment of a bar lens according to the invention, in which the incident beam and the emergent beam lie on different planes,

Figure 17 shows a view of the bar lens in Figure 16 in the direction of arrow B toward its one front side,

Figure 18 shows a top view of a further embodiment of a bar lens according to the invention with a round base bar and attached prisms,

Figure 19 shows section XIX-XIX as shown in Figure 18,

Figure 20 shows section XX-XX as shown in Figure 18,

Figure 21 shows a top view of a further embodiment of a bar lens according to the invention with a round base bar,

Figure 22 shows section XXII-XXII as shown in Figure 21,

Figure 23 shows an optical transmission system consisting of bar lenses for a stereoendoscope, that has been modified from Figure 1, and

Figure 24 shows a very simplified monocular endoscope with beam displacement.

The same reference numbers are used in the various embodiments to represent the same or corresponding parts.

Figure 1 shows a stereoendoscope with a rigid, cylindrical shaft 1 that culminates at its proximal end 2 in a headpiece 3, whose diameter is significantly larger than the diameter of the shaft 1. There are two lenses 5 and 6 at the distal end 4 of the shaft that are only depicted schematically as lenses. Two guide tubes 7 and 8 run in parallel to each other in shaft 1, in which several bar lenses 9 and 10 and/or 9a and 10a are arranged in succession, which belong to two optical transmission systems 9 to 11 and 9a to 11a, respectively, through which the beams entering both lenses 5 and 6 are transmitted to two oculars or adapting optics 12 and 13 for a subsidiary imaging or image taking device that is located in the headpiece 3.

In shaft 1 both optical transmission systems have only a small distance *b* between their optical axes 14 and 15, whereas the optical axes 16 and 17 of the oculars have a larger distance *a*, such as the distance between the eyes or a common specified distance that is set for a subsidiary image taking or imaging device, such as a camera. Because of this, the endoscope must be provided with a beam displacement mechanism. For this purpose, a further bar lens 11 or 11a is provided in at least one of the two beam paths, in the diagrammed example according to Figure 1 in each of the two beam paths in headpiece 3, in which an array of prisms is integrated that ensures a twofold right-angle beam deviation and therefore parallel beam displacement.

The two beam paths in the endoscope are mirror images of each other: for this purpose, lenses 5 and 6, the bar lenses 9 and 9 a, bar lenses 10 and 10a, bar lenses 11 and 11a, and oculars 12 and 13 are configured identically to each other, and bar lenses 11 and 11a are situated in a mirror relationship to each other. The bar lenses in the shaft 1 each consist of one cylindrical base bar 18 with flat end faces, on which a single lens 19 is bonded to one side and a twofold lens 20 is bonded to the opposite side. This arrangement is only depicted as an example, and other arrangements of bar lenses are certainly possible.

Bar lens 11 has, for example, one base bar 21 with a rectangular cross-section and flat end faces 22 and 23 that are parallel to one another. A single lens 25, whose optical axis is coincident with the optical axis 16 of the ocular 12, is bonded to the circumferential surface 24 that lies opposite to the end face 22. A twofold lens 27, whose optical axis coincides with the optical axis 15 of the shaft 1, is bonded to the circumferential surface 26 of the base bar 21 that is opposite to the end face 23.

A light beam entering lens 5 passes through bar lenses 9 and 10 as well as the twofold lens 27, is reflected by the diagonal end face 23 and again by the diagonal end face 22, passes through the single lens 25 and reaches the ocular 12. Another light beam enters the other lens 6 and reaches ocular 13 in a corresponding way.

Instead of oculars 12 and 13, adapting optics could also be provided with which the stereoendoscope can be connected to a camera. The term ocular is here meant in a general sense to include such adapting optics to adapt a camera for other imaging processes.

Figures 2 to 6 show examples of bar lenses that only cause beam deviation at one of their ends. The bar lens depicted in Figures 2 to 4 has a rectangular base bar 21 whose end face 22 is diagonal to the longitudinal axis of the base bar, and whose other end face 23 runs at right angles to the longitudinal axis 28 of the base bar. Of the circumferential surfaces of the base bar 21, at least circumferential surface 24 is polished; and face 22 is preferably mirrored. The circumferential surface 24 that is opposite to end face 22 has a single lens 25 that is circular in cross-section; the opposite end face 23 has a twofold lens 27. Lenses 25 and 27 are bonded to the base bar.

Lenses 25 and 27 preferably have a diameter that is congruent with the lateral length of the cross-section of the base bar 21. However, it is also possible to select one or another lens, particularly the lens 25 attached to the circumferential surface, that is larger (Figure 5) or smaller (Figure 6); this can be advantageous for installation into the endoscope housing, or in calibration.

Figures 7 to 11 show an embodiment of bar lenses with twofold beam deviation. The bar lens depicted in figures 7 to 9 has a design as it is used in an endoscope according to Figure 1, with bar lenses 11 and 11a. Bar lens 11 has a base bar 21 with two flat end surfaces 22 and 23 that are preferably mirrored and that are parallel to each other and run diagonal to the longitudinal axis 28 of the base bar. A single lens 25 is bonded to the circumferential surface 24 that is opposite the end face 22. A twofold lens 27 is bonded to the circumferential surface 26 that is opposite the end surface 23. At least the areas of circumferential surfaces 24 and 26 that lie below lenses 25 and 27 are polished. The other circumferential surfaces do not need to be polished.

Lenses 25 and 27 are circular in cross-section and have a diameter that is equal to the lateral length of the rectangular cross-section of base bar 21. Here, too, modifications are possible in which lenses 25 and 27 are smaller (Figure 10) or larger (Figure 11).

The base bar of the bar lens according to the invention does not need to be rectangular or square in cross-section, but can have other cross-sectional forms. One example of a cross-section in the form of a regular hexagon is shown in figures 12 and 13 with one or two slanting end faces 22 that are preferably mirrored, and another with a lens 25 that is circular in cross-section that is bonded to the circumferential surface that is opposite the slanted end face. Instead of a regular hexagon, other regular or irregular cross-sectional forms may be used. These are particularly suitable for variants in which the beam not only passes in parallel through the plane that is formed by the optical axes 14 and 15 in shaft 1 of the stereoendoscope (see Figure 15), but is also deviated at an angle to this plane (see figures 16 and 17).

The bar lens depicted in Figure 15 differs from the bar lens in Figure 7 in that the base bar 21 has two end faces to each of which is bonded a triangular prism 29 and 30, and that run vertical to the longitudinal axis 28. The prisms are positioned such that when observing the principal beam, the incident beam 31 and the emergent beam 32 lie on a common plane E. However, if the prism 30 is rotated around the longitudinal axis 28 of the base bar by angle x (Figure 17) then the emergent beam 32 no longer lies along the

plane E, but rises above plane E by angle x. If one places two such bar lenses as depicted in figures 16 and 17 in succession in the beam path, the emergent beam then runs along a plane that is parallel to plane E, i.e., not only can the beam be displaced parallel laterally but also parallel in another plane.

This type of displacement may be achieved both with base bars that are canted in cross-section as well as with those that are round or semicircular in cross-section.

Figures 18 to 22 show embodiments of bar lenses according to the invention with base bars that are round in cross-section. Figures 18 to 20 show a bar lens with a cylindrical base bar 21 that has two end faces to each of which has been bonded a triangular prism 29 and 30, respectively, to each of which in turn has been bonded a twofold lens 27 and/or a single lens 25, and that run vertical to the longitudinal axis of the base bar. The prisms each have a rectangular cross-section of incidence and cross-section of emergence 33 whose lateral length is congruent with the diameter of the base bar 21. In the embodiment depicted in figures 21 and 22, a bar lens has a cylindrical base bar 21 with end faces 22 and 23 that are preferably mirror images and that are parallel to each other and flat, and that are slanted to the longitudinal axis 28 of the base bar. Corresponding polished cylindrical lenses 25 and 27, respectively, are bonded to the cylindrical circumferential surfaces 24 and 26 that lie opposite to these surfaces, and whose diameter is preferably congruent with the diameter of the base bar 21, but can also be modified such that it is smaller or larger.

Figure 14 shows a modification of the example from Figure 21 such that instead of a cylindrical base bar 21 a base bar is used that has the form of a circular section in cross-section, where a lens 25 is bonded to the flat section of the circumferential surface that is opposite to slanted end face 22.

Figure 23 shows an example for a stereoendoscope in which three bar lenses, 41, 42, and 43, and 41a, 42a, and 43a, respectively, are provided in each of the two beam paths in the shaft, and two other bar lenses 44 and 45, and 44a and 45a, respectively are provided in

the headpiece, between each of which one bar lens 11 and 11a, respectively, is situated with an integrated arrangement of prisms.

The invention is not only suitable for stereoendoscopes, but also for monocular endoscopes. One such example is shown in Figure 24. The shaft 1 of this endoscope is offset at a right angle, in which case a bar lens 11 according to the invention is provided to bend the beam path 33, for which only the position is indicated in Figure 24. A free space 34 in the anterior area of the endoscope is gained by this right-angle offset, in which instruments can be operated that are passed through an access channel 35 in the shaft.

Claims:

1. Rigid endoscope

having a shaft in which at least one lens and subsequent bar lenses of an optical transmission system that are connected with it, are provided at the distal end,

and having a headpiece at the proximal end of the shaft with at least one ocular or one adapting optic for an image taking or imaging device subordinate to the endoscope, in which case the optical axis and/or the ocular of the adapting optic does not coincide with the optical axis of the associated transmission system in the shaft,

for which reason, an arrangement of prisms for bending the beam path is provided in the headpiece between the optical system in the shaft and the ocular,

characterized in that the arrangement of prisms is a component of a bar lens (11, 11a).

2. Endoscope according to claim 1, **characterized in that** the bar lens (11, 11a), whose component is the prism arrangement, has a base bar (21) with two flat end faces that run at a right angle to its longitudinal axis (28), and in that a prism (29, 30) is provided and in particular bonded, at one or both end faces with one of its entry or exit faces (33), respectively, and in which a lens (25, 27) is provided, and in particular bonded, to one or both prisms (29, 30) at its or their other entry or exit face (33).

3. Endoscope according to claim 1, **characterized in that** the bar lens (11, 11a), whose component is the prism arrangement, has a base bar (21) with one or two flat end faces (22, 23) that are, in particular, parallel, and that are diagonal to its longitudinal axis (28), and in that a lens (25, 27) is attached, in particular bonded, to the bordering circumferential surface (24, 26) of the base bar (21) that lies opposite to one or both end faces (22, 23).

4. Endoscope according to one of the previous claims, **characterized in that** the prisms are triangular prisms, rhomboidal prisms, or rhomboid-like prisms.

5. Endoscope according to one of the previous claims, **characterized in that** the arrangement of prisms is selected such that when observing a principal beam, the incidence beam (31) and the emergent beam (32) pass along different planes.